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THE NRC STRESSALYSER. A GENERAL-PURPOSE PURSUIT TRACKING TASK F--ETC(U)
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THE NRC STRESSALYSER: A GENERAL-PURPOSE PURSUIT TRACKING TASK FOR FIELD AND LABORATORY STUDIES

BY

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THE NRC STRESSALYSER: A GENERAL-PURPOSE PURSUIT TRACKING TASK FOR FIELD AND LABORATORY STUDIES

(LE 'STRESSALYSER' DU CNRC: UNE TÂCHE DE POURSUITE POLYVALENTE QUI SE DESTINE AUX ÉTUDES AU DEDANS ET AU DEHORS DU LABORATOIRE)

by/par

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ABSTRACT

The stressalyser is a step-input, subject-paced, pursuit tracking task developed in the Control Systems and Human Engineering Laboratory of the Division of Mechanical Engineering for use in measuring performance impairment under adverse conditions, and in studying motor control. The instrument produces measures of several aspects of the subject's performance following stress. Results of published studies are briefly reviewed and some new potential applications are indicated.

RÉSUMÉ

On a mis au point, dans la Laboratoire des systèmes de commande et d'ergonomie de la Division de génie mécanique, un instrument ayant pour buts de mésurer la diminution de la performance effectuée par des conditions défavorables, et d'étudier la psychomotricité humaine. Cet appareil, que l'on nomme 'stressalyser', est une tâche de pursuite pas-à-pas à la commande du sujet. L'instrument fournit des mésures de quelques aspects de la performance du sujet, qui permet faire une analyse précise des changements de performance suivante au stress psychologique. On a brèvement revisé les resultats des études déjà publiées, et on a signalé des nouvelles applications.

CONTENTS

TABLES

ILLUSTRATIONS

THE NRC STRESSALYSER: A GENERAL-PURPOSE PURSUIT TRACKING TASK FOR FIELD AND LABORATORY STUDIES

INTRODUCTION

Experimenters have used tracking tasks to investigate the mechanisms of human information processing, and, in a different context, to study the effects of various conditions extrinsic to the task upon performance. A case in point is that of Gibbs, who devised a task for investigating the role of kinaesthetic feedback in skill acquisition (Gibbs, 1965), and then went on to use the same task to study impairment resulting from alcohol ingestion (Gibbs, 1966). In view of this secondary use he named his device a stress analyser, subsequently shortened to 'stressalyser'. Following his death in 1968 we developed his concept to produce the general-purpose tracking task described in this paper.

DESCRIPTION OF TRACKING TASK

The stressalyser is a step-input, subject-paced, pursuit tracking task (Fig. 1). The subject faces a display of five lamps, one of which is illuminated to designate the target. His task is to align the pursuit element with the target by means of the two-handed control wheel. Following precise alignment the target moves to another position. A trial consists of 100 consecutive target presentations.

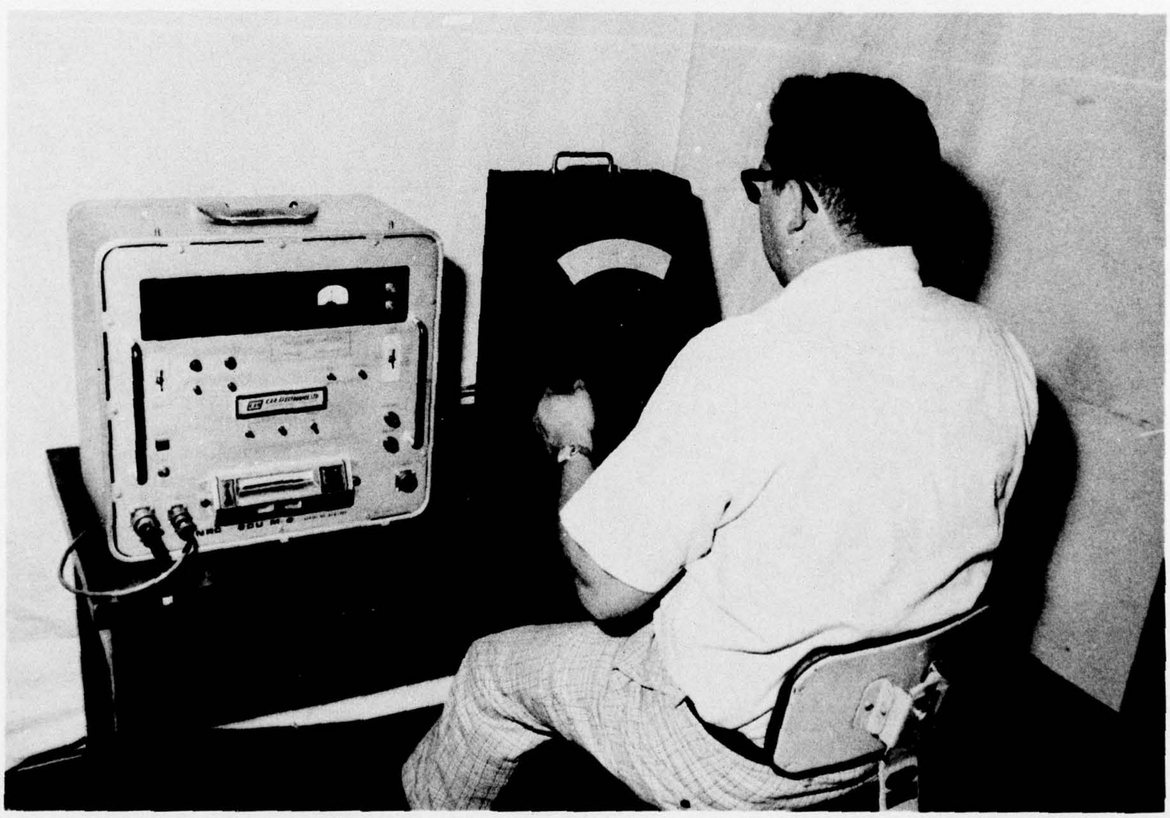

FIG. 1: A SUBJECT PERFORMING ON THE STRESSALYSER

A basic feature of the task is that the probability of left versus right target movement varies according to the location of the previous target. Taking the five positions numbered 1 to 5 from left to right across the display, these probabilities are 0:1, 0.25:0.75, 0.5:0.5, 0.75:0.25 and 1:0. For this to be the case the twenty possible movements between pairs of positions must occur equally frequently during the trial, but it is the physical appearance of the display which makes these probabilities clear to the subject. This is one reason why the task requires pursuit rather than compensatory tracking. The same sequence of movements could be presented to the subject by moving the pursuit element instead of the target but the probability characteristics would be less evident. Other reasons for using a pursuit mode are the relative ease of embodying it in a mechanical device, and the greater appeal that it has for the subject.

The tracking unit is simple and robust in design. The targets are ends of optic fibres originating at lamps placed in a readily accessible compartment. The pursuit element is mounted on a rotating pointer driven by the control wheel through a drum and band system with virtually no backlash. The system has an inertia of 9.56 gm^2 and requires an applied torque of 14.2 gm to initiate movement. The two-handed wheel is styled to facilitate a standard grip which allows the subject to exercise fine control (Fig. 2).

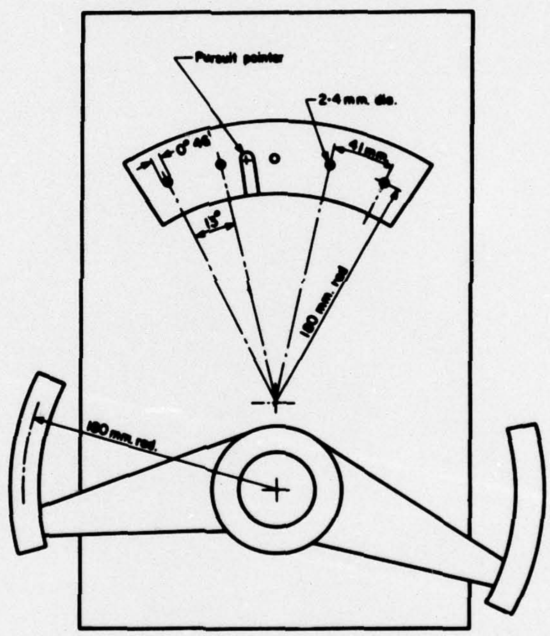

FIG. 2: PLAN OF THE TRACKING UNIT DISPLAY AND CONTROL WHEEL

Subjects prefer the pursuit mode because they retain control of the pursuit element: in the compensatory mode control is momentarily lost when the target is aligned and the pursuit element moves of its own accord. This feeling of control is further enhanced by using subject- rather than experimenter-paced target presentation. The subject knows when he has successfully aligned the target. He knows also that the faster he moves, the faster the target moves through its sequence, and total time taken gives a simple, readily available overall measure of performance. The subject competes with himself to produce a better score, and the task has, in fact, a pin-table appeal which facilitates subject co-operation and goodwill even in circumstances where self-administration is required.

We adopted subject-pacing in place of the experimenter-paced procedure originally used by Gibbs primarily in order to provide a known basis for measuring reaction time and other performance

indices at each step. If the subject were still executing his response at the point when the target moved information about the time and precision of the previous movement and the reaction time and accuracy of the next movement would be lost. This decision necessitated choice of a temporal as well as a positional criterion for defining precise alignment. Without the former a rapid excursion of the pursuit element across the target would trigger the next target. On a trial-and-error basis we chose 200 msec as an appropriate criterion which seemed to avoid the rapid excursion problem while not leaving too long for the subject to start wondering whether he was in fact precisely aligned. This choice appears to fit well with recent views on the time needed for visual feedback in positioning movements. We set the positional criterion at 2.4 mm, the width of the optic fibre (Fig. 2).

Although we abandoned Gibbs' choice of experimenter-pacing we retained his use of a conventionally incompatible control-display configuration: clockwise rotation of the wheel produces right to left movement of the pursuit pointer. This feature, relating to his interest in skill acquisition, proved relevant to performance impairment in that it increases task difficulty, making performance more susceptible to the effects of external stress. However, it also increases initial practice effects, and as with any psychomotor test, subjects must be trained on the stressalyser before being exposed to the experimental condition since practice effects would otherwise swamp condition effects.

TIME MEASUREMENTS

The step-input structure of the task, together with the subject-paced procedure, allows us to measure the subject's response at each target presentation in terms congruent with classical performance measures (Fig. 3). Reaction time is defined as the interval between target presentation and the initiation

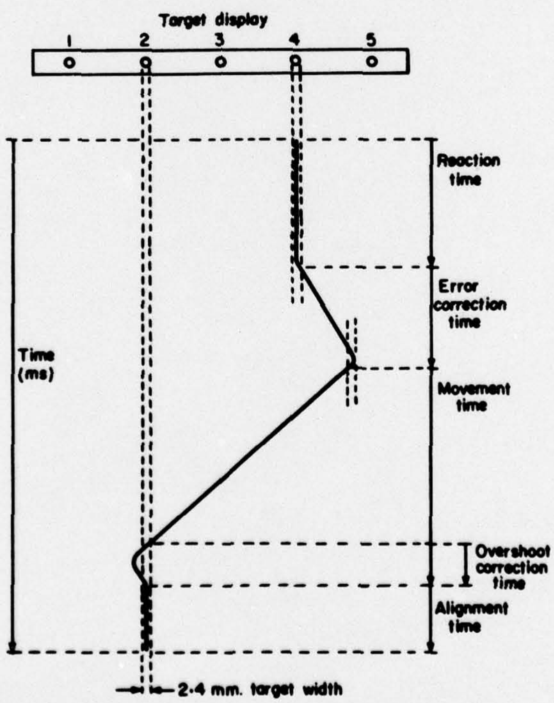

FIG. 3: SCHEMATIC OUTLINE OF A RESPONSE FOLLOWING A TARGET MOVEMENT FROM POSITION 4 TO POSITION 2.

REACTION TIME TERMINATES WHEN THE PURSUIT ELEMENT MOVES BEYOND ONE-HALF TARGET WIDTH FROM THE PREVIOUS TARGET CENTRE. ERROR CORRECTION TIME TERMINATES WHEN THE PURSUIT ELEMENT MOVES IN THE CORRECT DIRECTION A DISTANCE EQUIVALENT TO THE TARGET WIDTH. OVERSHOOT CORRECTION TIME COMMENCES WHEN THE PURSUIT ELEMENT MOVES TO WITHIN ONE-HALF TARGET WIDTH OF THE TARGET CENTRE.

of pursuit movement. Error correction time is defined as the interval between initiation of pursuit movement and initiation of movement towards the target. This term is somewhat misleading, implying as it does that the error is not detected until after the response is initiated and that it is not corrected until after the direction of movement has been reversed, but the defined interval does provide a simple computational procedure for counting errors. When a correct response is made the two events coincide and the interval is zero.

Movement time is defined as the interval between initiation of movement towards the target and the commencement of the 200-msec criterial alignment period. This interval is divided for computational purposes into two components, acquisition time and overshoot correction time, based on the point when the pursuit element first arrives at the target. This latter term is also somewhat misleading, with its implications about detection and correction of overshoots, but the defined interval provides a simple computational procedure for counting overshoots. When no overshoot occurs the 200-msec criterial alignment period begins immediately the pursuit element reaches the target and the interval is zero. This computational procedure includes as overshoots those responses where the pursuit element moves on to the target and then withdraws to the original side without actually crossing the target. In this, as in the target-crossing case, a reversal of direction has occurred, implying that the subject perceived his response as an overshoot.

For each target presentation, therefore, we make two interval measurements, reaction time and movement time, and two event measurements, error incidence and overshoot incidence. Four hundred measurements are made in the course of one trial lasting 2-3 minutes.

TASK CONTROL AND DATA RECORDING

The defined intervals are measured by a control unit which identifies the criterial events. The control unit energises (at 10 V dc) a potentiometer driven by the control wheel which returns an analog representation of the position of the pursuit element. This is compared with one of five standard voltages corresponding to the five lamp positions set up on a tuned resistor network. Before operating the apparatus this network must be calibrated to ensure that electrical alignment corresponds with optical alignment, and that the electrical width of the target corresponds with optical width.

The control unit energises the appropriate target lamp, and selects the corresponding resistor calibration, in a sequence determined by a hard-wired target selection board. The five outputs from this board are permutated by a target pattern selection switch before being used to determine the sequence, so that in fact ten patterns or sequences are available for use. Other patterns can be obtained by changing the board, but ten are sufficient for the normal purpose of maintaining the apparent randomness of target movement as the subject proceeds from trial to trial. All patterns begin and end with targets presented at the middle of the display (Position 3), and all include five each of the twenty possible movements between positions.

In order to avoid operational noises which the subject might use to monitor his performance, the data recording system uses a continuously running magnetic tape. This means that data are written at unequally-spaced intervals, and consequently the data must be retrieved by a special decoding procedure for conversion to a computer-compatible format. While this may be regarded as a shortcoming of the overall system, it is warranted by the elimination of spurious auditory cues. In any case, the system is relatively inexpensive, but nonetheless reliable, and uses readily available audio-cassette tapes. The recording system can be bypassed by linking the control unit to the computer-controlled decoding system, but this of course restricts the apparatus to laboratory use.

The control unit weighs 21 kg and requires a power supply of either 110 V 60 Hz or 220 V 50 Hz. It carries a digital second-counter which displays the total time taken for a trial (to provide immediate knowledge of results), and produces an analog voltage for tracing pointer movement on a pen recorder, and a pulse voltage at each target presentation.

The complete stressalyser system consists of the tracking unit, the control unit, and a data decoding module for use in a CAMAC system (Hyde, Note 4). Supporting software includes FORTRAN programs for decoding and editing the recorded data, and programs for statistical analysis of the edited data (Buck, Green, Hyde, Isnor & Leonardo, Note 2; Isnor, Note 5).

DATA ANALYSIS

Stressalyser performance improves rapidly with practice over several trials. We trained 150 subjects during the course of several experiments using a standard procedure of sixteen consecutive trials, divided by short rest pauses into blocks of four. Total response times (mean interval between successive target presentations less 200 msec) decreased to a minimal value at Trial 14, with most improvement occurring in the earlier trials (Table 1). The last trial to yield a mean score significantly lower than that of the previous trial was Trial 14.

TABLE 1

TOTAL RESPONSE TIME SCORES FOR SIXTEEN CONSECUTIVE TRAINING TRIALS (n = 150)

Trial	1	2	3	4	5	6	7	8
Mean	1643	1468	1416	1381	1311	1293	1296	1290
SE	23.3	15.2	14.1	13.6	12.8	12.9	12.9	12.8
Trial	9	10	11	12	13	14	15	16
Mean	1254	1229	1235	1241	1223	1209	1216	1214
SE	11.8	12.6	12.1	11.4	11.9	12.3	12.3	11.9

The distributions of measured intervals (reaction time, etc.) in Trials 13-16 were bell-shaped, if not actually gaussian, although all tended to have a few high values forming long positive tails. Those for error correction times and overshoot correction times greater than zero were also exceptional in having a number (1.9% and 0.3% respectively) of very low-valued data which were not distributed coterminously with the main body of data. Presumably these represented artifacts arising from characteristics of the detection circuits in the control unit. In all events they indicate that one should not use a criterion of any error correction time or overshoot correction time greater than zero to designate error and overshoot. Better criteria appear to be 11 msec for error correction time and 51 msec for overshoot correction time.

In analysing these data we first categorized by movement, and we distinguished between correct reaction times and those associated with error responses, and between movement times for overshoots and non-overshoots. The number of data in each movement category depended therefore on the incidence of error or overshoot, and it was considered desirable to average for data within a trial before averaging across trials and subjects. (With the large number of data involved here however, the arithmetical results of two-stage and one-stage averaging were virtually identical.) Errors and overshoots were expressed as the percentages of such incidents among the 3000 responses in each movement category.

RESULTS

The results of these procedures are given in Tables 2 and 3 which show the relationships between the various performance indices on one hand and the task variables on the other. Reaction times associated with correct responses, and error rates, depend on directional probability. Reaction times associated with error responses by contrast appear to be unaffected by this or any other task variable, except that those for movements starting from Positions 1 and 5 are generally lower than the others. (These latter values are also based on much fewer data.) Movement times for both overshoot and non-overshoot responses depend on the distance between starting and target positions. The values for different movements of a given distance are more variable than is the case for correct reaction times of a given probability, but these variations do not appear to be related to any other task variable. Movement times associated with overshoot responses are generally longer than those associated with non-overshoots. Whether or not the response was an error makes neither a significant, nor even a systematic, difference to movement time, and this was not taken into account when categorizing movement times. (Some movement times associated with error responses were shorter than those in the same movement category following correct responses, even though, because of the initial movement in the wrong direction, a longer distance had to be travelled.) Overshoot rate depends on the distance of the target from the boundary of the display. This relationship is discussed more fully elsewhere (Buck, 1976a, 1978).

TABLE 2

REACTION TIME (MEAN AND STANDARD ERROR IN MILLISECONDS) FOR CORRECT RESPONSES AND ERROR RESPONSES, AND PERCENTAGE OF ERROR RESPONSES, FOR EACH MOVEMENT

Starting Position	Target Position				
	1	2	3	4	5
1	—	231 2.0 119 15.3 1.2	236 2.0 126 17.3 1.5	237 2.1 133 15.2 1.8	231 2.0 145 18.0 1.7
2	327 3.7 269 2.1 54.7	—	287 2.4 245 6.5 10.8	286 2.4 272 5.2 14.1	283 2.6 275 5.8 11.6
3	313 2.8 280 2.9 33.8	321 2.7 266 3.6 25.8	—	317 3.1 272 3.2 32.3	319 2.9 280 3.3 30.3
4	284 2.5 266 6.8 10.6	287 2.3 245 5.0 15.8	290 2.4 263 5.5 14.1	—	325 3.9 262 2.4 52.8
5	238 2.1 117 13.3 2.2	236 2.1 121 13.0 2.6	238 2.1 109 9.0 2.5	237 2.1 128 13.7 2.2	—

TABLE 3

MOVEMENT TIME (MEAN AND STANDARD ERROR IN MILLISECONDS) FOR NON-OVERSHOOTS AND OVERSHOOTS, AND PERCENTAGE OF OVERSHOOTS, FOR EACH MOVEMENT

Starting Position	Target Position 1	Target Position 2	Target Position 3	Target Position 4	Target Position 5
1	—	673 8.1 1040 14.5 51.7	781 7.6 1222 16.1 38.8	899 8.0 1343 16.9 35.6	1041 8.6 1474 22.8 23.7
2	633 6.1 1101 18.0 24.0	—	606 7.2 983 12.8 41.3	777 7.5 1192 15.5 35.5	966 8.6 1378 21.8 22.2
3	791 7.1 1219 19.8 25.0	591 6.3 1046 14.1 33.7	—	613 6.8 1030 13.4 35.6	801 7.8 1234 20.8 25.4
4	940 7.3 1370 20.2 21.3	748 6.7 1202 16.7 35.3	593 6.6 997 13.2 39.4	—	647 6.8 1153 22.8 25.2
5	1024 8.4 1473 22.2 22.4	880 7.4 1344 16.4 32.4	758 6.5 1245 16.5 38.1	646 8.9 1050 13.9 50.8	—

On the basis of these results we re-categorized our data in order to compute performance scores for the different levels of the appropriate task variables. In addition we categorized total response times according to the quarter of the trial in order to provide a measure of performance changes during the course of the trial. We did not compute error reaction time scores because of the relatively small numbers of data. From the 400 data collected for each trial we were thus able to compute six scores describing various aspects of the subject's performance, each at four levels of the relevant task variable. Table 4 (page 8) shows mean scores for our 150 subjects on the last four trials of the training session, and the relations between each performance measure and the appropriate task variable. The observed relations serve to validate our technique for measuring psychomotor performance.

APPLICATIONS

Since this task was first conceived by Gibbs, a number of investigators have used the stressalyser to measure performance under various adverse conditions. Carpenter, Gibbins and Marshman (1975) used the original experimenter-paced version in their study of the effects of alcohol and meprobamate. Other experimenters (Burford, French & LeBlanc, 1975; Fraser, Buck & McKendry,

TABLE 4

PERFORMANCE SCORES AS RELATED TO THE APPROPRIATE
TASK VARIABLE (n = 600, EXCEPT AS INDICATED)

Correct reaction time score (milliseconds)				
directional probability	1.00	0.75	0.50	0.25
mean	235	286	316	323[1]
SE	1.7	1.9	2.2	3.3
Non-overshoot movement time score (milliseconds)				
target distance	1	2	3	4
mean	621	777	924	1030
SE	4.6	5.6	6.4	7.7
Overshoot movement time score (milliseconds)				
target distance	1	2	3	4
mean	1049	1239[2]	1383[3]	1500[4]
SE	8.5	10.6	13.0	19.1
Total response time score (milliseconds)				
quarter	1	2	3	4
mean	1200	1216	1224	1221
SE	6.3	6.6	6.8	6.8
Error score (percentage)				
directional probability	1.00	0.75	0.50	0.25
mean	2	13	30	53
SE	0.1	0.3	0.5	0.7
Overshoot score (percentage)				
boundary distance	1	2	3	4
mean	23	34	39	51
SE	0.5	0.7	0.8	1.0

[1] n = 594 [2] n = 598 [3] n = 589 [4] n = 516

Missing data represent trials where no correct response, or no overshoot, occurred among movements of the indicated level of task variable.

1974; McLaughlan, Usher, Noel & Moodie, 1976; Orr, Dussault, Chappel, Goldberg & Reggiani, 1976) used the subject-paced version in their studies of alcohol and other drugs. In a different area, Buck (1975, 1976b, 1977) and Buck and Gibbs (1972) have used the device in studies relating to sleep loss and circadian rhythms.

Some of these investigators used gross measures of impairment based on total response time scores, but others have shown differential effects of the experimental condition on the detailed performance measures. Fraser et al (1974) and Buck (1976) showed that movement time scores were more impaired by hypoglycemia and sleep loss, respectively, than were reaction time scores, while Orr et al (1976) showed that dose-related effects of diazepam resulted in an initial decrease in reaction time scores as movement time scores increased. Buck (1977) showed that time of days effects on performance speed were out of phase with the effects on performance accuracy.

In all the cases cited above the aim has been to detect differences between conditions, but our training data have shown differences between individuals relating to age and sex (Buck, Note 1), and more recent unpublished data indicate a use for the instrument in the field of driver-aptitude testing. The system has thus proved to be a useful method for measuring psychomotor performance, with actual and potential application in several research areas.

Apart from studying the effect of adverse conditions upon performance, the stressalyser continues to be used for studies of movement control of the kind first envisaged by Gibbs (Buck, 1976a, 1978). These studies usually require a more flexible system than the one used for studies of stress, but this can be obtained. For example, non-standard target sequences can be obtained by modifying the target pattern board. We have also designed and constructed an interface module which uses the output from the control unit to drive an oscilloscope (Hyde, Note 3). By this means we can introduce variations in both the display and the subject's controller while using the control unit to program the task and to measure and record performance. What is retained in such circumstances are Gibbs' original ideas relating to directional probability, display-control compatibility, and so on.

Gibbs' ideas have also been used by Megaw (1972a, b), Megaw and Armstrong (1973), and Landauer, Milner and Patman (1969) in experimental devices quite different to our stressalyser system.

FUTURE DEVELOPMENTS

We are now endeavouring to apply microprocessor techniques to the stressalyser system, hoping by this means to reduce the size and weight of the control unit, to produce a more efficient data recording system, and perhaps to introduce additional flexibility into the system. The major shortcoming of the present system, in our view, is the comparative complexity of the data decoding procedure, and we hope at least to reduce this, without on the other hand losing the present advantages of noiseless operation and a readily available source of magnetic tapes. We do not intend however to change the tracking unit in any significant way, so that the task as the subject perceives it will remain the same, and new data will remain directly comparable to data already collected and published.

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National Research Council Canada. Division of Mechanical Engineering.

THE NRC STRESSALYSER: A GENERAL-PURPOSE PURSUIT TRACKING TASK FOR FIELD AND LABORATORY STUDIES.
Buck, Leslie, Leonardo, R., Hyde, F. June 1978. 14 pp. (incl. tables and figures).

The stressalyser is a step-input, subject-paced, pursuit tracking task developed in the Control Systems and Human Engineering Laboratory of the Division of Mechanical Engineering for use in measuring performance impairment under adverse conditions, and in studying motor control. The instrument produces measures of several aspects of the subject's performance following stress. Results of published studies are briefly reviewed and some new potential applications are indicated.

UNCLASSIFIED

1. Pursuit tracking.

I. Buck, Leslie.
II. Leonardo, R.
III. Hyde, F.
IV. NRC, DME ML-6